

Claims:

1. A method of processing a digital image, comprising the steps of:

providing digital data indexed to represent positions of an image having S spectral bands for simultaneous output on a display, said digital data being indicative of an intensity value $I_i(x,y)$ for each position (x,y) in each i-th spectral band;

defining a classification of said image based on dynamic range of said image in each of said S spectral bands;

adjusting said intensity value for said each position in each i-th spectral band to generate an adjusted intensity value for said each position in each i-th spectral band in accordance with

$$\sum_{n=1}^N W_n (\log I_i(x,y) - \log [I_i(x,y) * F_n(x,y)]), \quad i=1, \dots, S$$

where S is the number of unique spectral bands included in said digital data and, for each n, W_n is a weighting factor and $F_n(x,y)$ is a unique surround function applied to said each position (x,y) and N is the total number of unique surround functions; and

filtering said adjusted intensity value for said each position of said image in each of said S spectral bands using a filter function based on said classification of said image wherein a filtered intensity value $R_i(x,y)$ is defined.

1 2. A method according to claim 1 wherein each said unique
2 surround function is a Gaussian function.

1 3. A method according to claim 2 wherein said Gaussian
2 function is of the form

$$e^{\frac{-r^2}{c_n^2}}$$

3 satisfying the relationship

$$k_n \iint e^{\frac{-r^2}{c_n^2}} dx dy = 1$$

4 where

$$r = \sqrt{x^2 + y^2}$$

5 and, for each n, k_n is a normalization constant and c_n is a
6 unique constant for each of said N unique surround functions.

1 4. A method according to claim 1 further comprising the step
2 of multiplying said filtered intensity value $R_i(x,y)$ by

$$\log \left[\frac{B I_i(x,y)}{\sum_{i=1}^S I_i(x,y)} \right]$$

3 to define a color-restored intensity value $R'_i(x,y)$, where B
4 is a constant.

1 5. A method according to claim 1 wherein said each position
2 (x,y) defines a pixel of said display.

6. A method according to claim 1 wherein, for each n , $W_n=1/N$.

7. A method according to claim 1 wherein said step of defining comprises the step of using image statistics associated with said image in each of said S spectral bands to select said filter function.

8. A method according to claim 7 wherein said image statistics include brightness and contrast of said image in each of said S spectral bands.

9. A method according to claim 1 further comprising the steps of:

selecting a maximum intensity value $V_i(x,y)$ from the group consisting of said intensity value $I_i(x,y)$ and said filtered intensity value $R_i(x,y)$; and

displaying an improved image using said maximum intensity value $V_i(x,y)$.

10. A method according to claim 4 further comprising the steps of:

selecting a maximum intensity value $V_i(x,y)$ from the group consisting of said intensity value $I_i(x,y)$ and said color-restored intensity value $R'_i(x,y)$; and

displaying an improved image using said maximum intensity value $V_i(x,y)$.

11. A method of processing a digital image, comprising the steps of:

providing digital data indexed to represent the positions of a plurality of pixels of a J-row by K-column display, said digital data being indicative of an intensity value $I(x,y)$ for each of said plurality of pixels where x is an index of a position in the J-th row of said display and y is an index of a position in the K-th column of said display wherein a JxK image is defined;

convolving said digital data associated with each of said plurality of pixels with a function

$$e^{\frac{-r^2}{c^2}}$$

to form a discrete convolution value for each of said plurality of pixels, said function satisfying the relationship

$$k \iint e^{\frac{-r^2}{c^2}} dx dy = 1$$

where

$$r = \sqrt{x^2 + y^2}$$

k is a normalization constant and c is a constant;

converting, for each of said plurality of pixels, said discrete convolution value into the logarithm domain;

converting, for each of said plurality of pixels, said intensity value into the logarithm domain;

20 subtracting, for each of said plurality of pixels, said
21 discrete convolution value so-converted into the logarithm
22 domain from said intensity value so-converted into the
23 logarithm domain, wherein an adjusted intensity value is
24 generated for each of said plurality of pixels; and

25 filtering said adjusted intensity value for each of said
26 plurality of pixels with a filter function that is based on
27 dynamic range of said JxK image wherein a filtered intensity
28 value $R(x,y)$ is defined.

12. A method according to claim 11 wherein the value of said
constant c is selected to be in the range of approximately
0.01 to approximately 0.5 of the larger of J and K .

13. A method according to claim 11 further comprising the
steps of:

selecting, for each of said plurality of pixels, a
maximum intensity value $V(x,y)$ from the group consisting of
said intensity value $I(x,y)$ and said filtered intensity value
 $R(x,y)$; and

displaying an improved image using said maximum intensity
value $V(x,y)$.

1 14. A method of processing a digital image, comprising the
2 steps of:

3 providing digital data indexed to represent the positions
4 of a plurality of pixels of an J-row by K-column display, said
5 digital data being indicative of an intensity value $I_i(x,y)$
6 for each i-th spectral band of S spectral bands for each of
7 said plurality of pixels where x is an index of a position in
8 the J-th row of said display and y is an index of a position
9 in the K-th column of said display wherein a $(J \times K)_i$ image is
10 defined for each of said S spectral bands and a JxK image is
11 defined across all of said S spectral bands;

12 defining a classification of said JxK image based on
13 dynamic range of each said $(J \times K)_i$;

14 convolving said digital data associated with each of said
15 plurality of pixels in each i-th spectral band with a function

$$e^{\frac{-r^2}{c_n^2}}$$

16 for $n=2$ to N to form N convolution values for each of said
17 plurality of pixels in each said i-th spectral band, said
18 function satisfying the relationship

$$k_n \iint e^{\frac{-r^2}{c_n^2}} dx dy = 1$$

19 where

$$r = \sqrt{x^2 + y^2}$$

20 and, for each n , k_n is a normalization constant and c_n is a

21 unique constant;
 22 converting, for each of said plurality of pixels in each
 23 said i-th spectral band, each of said N convolution values
 24 into the logarithm domain;
 25 converting, for each of said plurality of pixels in each
 26 said i-th spectral band, said intensity value into the
 27 logarithm domain;
 28 subtracting, for each of said plurality of pixels in each
 29 said i-th spectral band, each of said N convolution values so-
 30 converted into the logarithm domain from said intensity value
 31 so-converted into the logarithm domain, wherein an adjusted
 32 intensity value is generated for each of said plurality of
 33 pixels in each said i-th spectral band based on each of said
 34 N convolution values;
 35 forming a weighted sum for each of said plurality of
 36 pixels in each said i-th spectral band using said adjusted
 37 intensity values; and
 38 filtering said weighted sum for each of said plurality of
 39 pixels in each said i-th spectral band with a filter function
 40 that is based on said classification of said JxK image wherein
 41 a filtered intensity value $R_i(x,y)$ is defined.

1 15. A method according to claim 14 wherein the value for each
 2 said unique constant c_n is selected to be in the range of
 3 approximately 0.01 to approximately 0.5 of the larger of J and
 4 K.

1 16. A method according to claim 14 further comprising the
2 step of multiplying said filtered intensity value $R_i(x,y)$ by

$$\log \left[\frac{B I_i(x,y)}{\sum_{i=1}^S I_i(x,y)} \right]$$

3 to define a color-restored intensity value $R'_i(x,y)$, where B
4 is a constant and S is a whole number greater than or equal to
5 2.

1 17. A method according to claim 14 wherein said step of
2 defining comprises the step of using image statistics
3 associated with each said $(J \times K)_i$ image to select said filter
4 function.

1 18. A method according to claim 17 wherein said image
2 statistics include brightness and contrast of each said $(J \times K)_i$
3 image.
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1 19. A method according to claim 14 further comprising the
2 steps of:

3 selecting a maximum intensity value $V_i(x,y)$ from the
4 group consisting of said intensity value $I_i(x,y)$ and said
5 filtered intensity value $R_i(x,y)$; and

6 displaying an improved image using said maximum intensity
7 value $V_i(x,y)$.

1 20. A method according to claim 16 further comprising the
2 steps of:

3 selecting a maximum intensity value $V_i(x,y)$ from the
4 group consisting of said intensity value $I_i(x,y)$ and said
5 color-restored intensity value $R'_i(x,y)$; and

6 displaying an improved image using said maximum intensity
7 value $V_i(x,y)$.

21. A method of processing a digital image, comprising the steps of:

providing digital data indexed to represent positions of an image having S spectral bands for simultaneous output on a display, said digital data being indicative of an intensity value $I_i(x,y)$ for each position (x,y) in each i-th spectral band;

defining a classification of said image based on dynamic range of said image in each of said S spectral bands;

adjusting said intensity value for said each position in each i-th spectral band to generate an adjusted intensity value for said each position in each i-th spectral band in accordance with

$$\sum_{n=1}^N W_n (\log I_i(x,y) - \log [I_i(x,y) * F_n(x,y)]), \quad i=1, \dots, S$$

where S is a whole number greater than or equal to 2 and defines the total number of spectral bands included in said digital data and, for each n, W_n is a weighting factor and $F_n(x,y)$ is a unique surround function of the form

$$e^{\frac{-r^2}{c_n^2}}$$

satisfying the relationship

$$k_n \iint e^{\frac{-r^2}{c_n^2}} dx dy = 1$$

where

$$r = \sqrt{x^2 + y^2}$$

20 and, for each n , k_n is a normalization constant and c_n is a
21 unique constant where N is the total number of unique surround
22 functions;

23 filtering said adjusted intensity value for said each
24 position in each i -th spectral band with a function based on
25 said classification of said image wherein a filtered intensity
26 value $R_i(x,y)$ is defined; and

27 multiplying said filtered intensity value $R_i(x,y)$ by

$$\log \left[\frac{B I_i(x,y)}{\sum_{i=1}^s I_i(x,y)} \right]$$

28 to define a color-restored intensity value $R'_i(x,y)$, where B
29 is a constant.

30 22. A method according to claim 21 wherein, for each n ,
31 $W_n = 1/N$.

32 23. A method according to claim 21 wherein the value for each
33 said unique constant c_n is selected to be in the range of
34 approximately 0.01 to approximately 0.5 of the larger of J and
35 K .

1 24. A method according to claim 21 wherein said step of
2 defining comprises the step of using image statistics
3 associated with said image in each of said S spectral bands to
4 select said filter function.

1 25. A method according to claim 24 wherein said image
2 statistics include brightness and contrast of said image in
3 each of said S spectral bands.

1 26. A method according to claim 21 further comprising the
2 steps of:

3 selecting a maximum intensity value $V_i(x,y)$ from the
4 group consisting of said intensity value $I_i(x,y)$ and said
5 color-restored intensity value $R'_i(x,y)$; and

6 displaying an improved image using said maximum intensity
7 value $V_i(x,y)$.
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